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Toward Seamless Ship-to-Drone Logistics: A Unified Regulatory and Operational Framework for Maritime-Port Integration

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ABSTRACT

The use of aerial vehicles or drones in maritime and port logistics can be transformative. Drones can potentially be utilized for several logistical activities, such as servicing ships, supporting offshore operations, inspecting, and conducting emergency deliveries. However, there are challenges that need to be mitigated before they are consistently operational. The greatest problem would be the existence of highly fragmented and unmatchable rules and regulations that govern the utilization of drones in the maritime environment. The governing rules and regulations for aviation, maritime and port operations lack coordination, which makes the drone-maritime integration difficult. This paper attempts to address this problem by creating a framework for adopting drones in maritime and port logistics. The framework focuses on dispatching drones for transportation of light-weighted but high value loads between ships in ports and near the shore destinations. The study used a combination of methods, including reviewing various regulations, interviewing stakeholders and looking at how drones are utilized in the ports. The findings identified three problems to solve: drone regulations are not well coordinated, the sectors do not work well together and there is no practical, standard procedures for operating drones in ports. To tackle these issues, the author proposes a framework in the basis of five approaches: harmonizing regulations, creating a digital system for getting permits, standardizing safety and security protocols, ensuring port environments are ready for drone flights, and coordinating governance for multi modal logistics. This framework supports port administrators, regulators and logistics operators to adopt sustainable and resilient utilization of drones. Deploying drone technology in maritime ports and ship-to-drone operations can be highly efficient, economical, and highly rewarding logistical solutions..

1. Introduction.

Maritime logistics systems and ports are facing a lot of pressure to respond quickly, reduce delays, be more resilient, and use technology. In this situation unmanned aerial vehicles or drones are an innovation for delivering things from ships to the shore quickly, inspecting things offshore, responding to emergencies, and transferring important documents, medical supplies and spare parts.

Early tests of drones in logistics show that they can reduce the time it takes to deliver things, make it safer to work in hard-to-reach areas, and help ships get serviced more quickly and efficiently. Even with these benefits, using drones for ship-to-shore delivery is not common and consistently utilized yet.

The main reason is not about the availability of the technology, rather lack of governing rules and regulations that streamline both aviation and maritime laws as well as how ports are run with the adoption of drones. Maritime logistics has established rules and laws. However, these rules are not suitable for drone operations, and often are confusing, restrictive or only apply to land-based mode of transportation.

As a result, there is a noticeable gap in governance when it comes to drones operating over the sea, especially when managing port airspace, keeping vessels safe, and controlling customs and security come to the picture. Even though there has been research on the application of drones in logistics, the practice of

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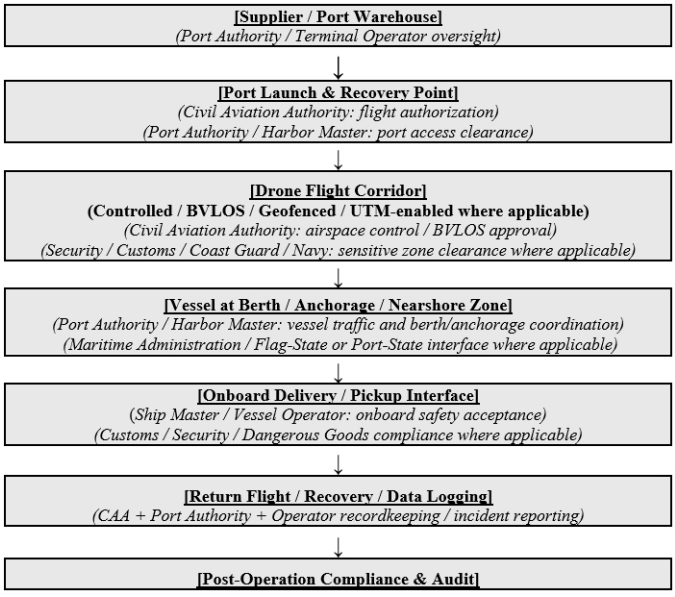
building smart ports and aviation governance, there is no or little information on how to make drone delivery effectively work in line with ships on the sea. Most of the research focuses on delivering loads on land, digitalizing ports or following aviation rules without visualizing on how all these enhancements work together seamlessly.

Therefore, a research gap exists when taking connecting maritime regulation, drone governance, and port operations into consideration, in such a way that ensures safety and scalability for ship-to-drone logistical integration.

To address this gap, this paper asks: How can we streamline maritime, and aviation rules work together for common goals and elevated results, to achieve scalable and interoperable ship-to-drone logistics?

The study develops a framework for regulating and operating drones in maritime environments based on a review of rules feedback from stakeholders and examples from around the world. Furthermore, this study contributes to the literature on logistics and governance of transportation, by proposing a practical framework for integrating drones into port operations. The proposed framework supports the modernization of maritime logistics while promoting safety, regulatory compliance, and interconnectivity.

Figure 1: Ship-to-Drone Logistics Operational Ecosystem.



Source: Authors.

Logistical advancements with the adoption of drone operations into maritime are crucial for the development of modern ports. Hence, this paper aims to provide an insightful solution to enable the safe and efficient integration of drone operations into maritime logistics and port systems. Utilizing drones in port logistics can bring numerous benefits, including faster delivery times, improved safety, minimized cost, and increased efficiency. Thus, this paper provides a practical and comprehensive framework to realize a successful integration of ship-to drone logistics, especially in the case of time sensitive, high-value, and light-weight transportation of goods.

The growing importance of drone operations in logistics highlights the need for practical governance solutions that support their safe integration into maritime transport, which is highly relevant to contribute to the advancement of the field in presenting a practical framework for integrating drone operations into existing maritime logistics systems and port management practices.

2. Literature Review And Research Gap.

Research on maritime logistics and port digitalization has increasingly highlighted the potential of drones to support a wide range of port activities, including infrastructure inspection, surveillance, inventory management, and time-critical services to vessels operating in areas that are difficult to access (Heilig and Voß, 2017; Heilig, Lalla-Ruiz and Voß, 2017). At the same time, studies on smart ports have shown that digital technologies can enhance the efficiency, sustainability, and resilience of maritime supply chains by improving operational visibility and decision-making (Cimino *et al*., 2017). In parallel, international aviation regulators have developed guidance for the safe operation of unmanned aerial vehicles (UAVs), with particular attention to issues such as airspace access, operational risk, pilot competency, and beyond visual line of sight (BVLOS) operations (International Civil Aviation Organization (ICAO), 2015; European Commission, 2019; European Union Aviation Safety Agency (EASA), 2024).

Although these developments provide an important foundation, they do not fully address the regulatory and operational requirements of ship-to-drone logistics. Much of the existing research has concentrated on urban air mobility and last-mile delivery, while applications involving ports, offshore facilities, and vessels have received comparatively less attention (Wang *et al*., 2023). Likewise, studies examining UAV regulation have tended to focus on civil aviation requirements, with limited consideration of how these interact with maritime law, port governance, and vessel operations (International Civil Aviation Organization (ICAO), 2015; European Commission, 2019; International Maritime Organization (IMO), 1974; United Nations, 1982). Research on smart ports has also acknowledged drones as an emerging technology, but relatively few studies have examined the institutional, legal, and operational arrangements needed to support their routine use in maritime environments (Heilig, Lalla-Ruiz and Voß, 2017; Cimino *et al*., 2017).

Taken together, the existing literature suggests that an integrated perspective on maritime law, UAV regulation, and port governance is still lacking. This paper seeks to address that need by presenting a practical framework to guide the integration of drone operations into maritime port logistics in a way that reflects both regulatory requirements and operational realities.

3. Methodology.

This study adopts an exploratory mixed-methods design to examine the legal, institutional, and operational conditions re-

quired for the integration of ship-to-drone logistics in maritime-port environments. The research is framework-oriented and combines three complementary evidence streams: (1) comparative regulatory review, (2) stakeholder evidence, and (3) international case evidence. This design was selected because ship-to-drone logistics remains an emerging field in which regulatory arrangements are fragmented, empirical deployment remains limited, and relevant insights are distributed across policy, operational, and institutional domains.

The study reviewed 18 regulatory instruments, each of drone and maritime laws, from eight jurisdictions. Semi-structured interviews were conducted with 12 experts, collated from Aviation, drone projects, port administrators and SC researchers. Four international port case studies were examined – Dubai, Port of Antwerp, Port of Rotterdam and Singapore.

A. Comparative Regulatory Review.

A purposive comparative review was conducted within the relevant jurisdictions of Africa and the Middle East, based on their significance and the level of development of their UAV regulations. The relevant jurisdictions were chosen based on three major factors: (i) strategic importance in terms of maritime logistics and ports, (ii) having UAV regulatory framework and drone policies in place, or (iii) relevance to smart ports. Four main aspects have been analysed during the process: (a) UAV authorizations and licenses, (b) BVLOS or riskier flights, (c) organizations that influence the implementation of drones in maritime transport, and (d) capacity of current regulations to accommodate ship-based missions.

B. Stakeholder Evidence.

As a complement to the regulatory assessment, aggregate evidence gathered from stakeholders through semi-structured interviews related to civil aviation, port management, maritime regulation, logistics management, and UAV service delivery was used. The stakeholder evidence is related to operational challenges, approval challenges, safety challenges, agency coordination problems, and feasibility issues. Owing to the exploratory nature of the research, in addition to ensuring compactness of the conference paper and maintaining double blindness, the stakeholder evidence is presented thematically.

C. International Case Evidence.

Again, there was a narrow review of international implementations and governance of drones within the ports sector. This was done with the intention of identifying the factors that facilitate such a system, operational issues, and governance challenges that are common to ship to drone operations. This is an analytical use of the cases where there is focus on the lessons from the implementation process of the drones for future purposes, rather than a description of the whole case.

D. Analytical Approach.

Findings from the three streams of evidence were synthesized via thematic synthesis and cross-source triangulation, whereby consistent themes emerged from the regulatory, stakeholder and international implementation perspectives and were then classified into categories of governance challenges and facilitators. Such an approach helped create a five-pillar framework for maritime-port governance that is based on convergent findings within the three streams of evidence. Thus, it should be noted that the resulting framework is not meant to be used only in a particular jurisdiction, but rather as an adaptable governance structure.

4. Findings And Analysis.

Three major findings emerged from the comparative and thematic analysis.

A. Maritime Governance Is More Mature Than UAV Governance.

In the context that has been examined, maritime regulations are characterized by relative stability and international consistency due to existing conventions and established practices. On the other hand, regulation of UAVs is characterized by inconsistency, fragmentation, and orientation towards control as opposed to enabling activities. This situation presents challenges to the use of drones in the maritime environment, especially when it comes to port areas.

B. Institutional Fragmentation Is the Main Deployment Bottleneck.

The biggest challenge in each case is not the capacity of the aircraft itself, but rather the lack of unified authority. The logistics involved in ship-to-drone transport would usually entail coordination between civil aviation authorities, port authorities, maritime regulation bodies, and even security agents in some instances. In many situations, there is no single body responsible for this process from end to end.

C. Operational Feasibility Exists, but Port-Specific Standards Are Missing.

According to the reviewed foreign practice, it can be stated that ship-to-drone logistics is technically possible to implement within the framework of tight control measures. There are four factors which allow successful implementation of such an innovative approach: operational zones, coordination of management, safety measures, and infrastructure preparedness. The mentioned aspects are faced with the following potential threats: crowded space above the port, communication problems, weather conditions, cyber security issues, and special cargo environment hazards.

5. Unified Regulatory And Operational Framework.

Based on the findings, this paper proposes a five-pillar unified framework for ship-to-drone logistics.

A. Regulatory Harmonization.

Maritime-related UAV rules need to be introduced into national and regional regimes, with standardization of definitions of ship-source and ship-destination activities; more clarity on

Table 1: Comparative regulatory gaps affecting ship-to-drone logistics.

Dimension	Current Situation in Many Jurisdictions	Maritime Implication	Operational Impact on Ship-to-Drone Logistics
UAV licensing and authorization	UAV rules exist but are often general and non-maritime specific	No clear treatment of vessel-interface operations	Delays in approvals and uncertainty for ship-origin/ship-destination missions
BVLOS permissions	Frequently restricted, case-by-case, or poorly defined	Limited legal basis for offshore or anchorage operations	Difficult to scale beyond pilot projects
Port airspace coordination	Aviation and port control systems often operate separately	No integrated port-UAV operational corridor	Increases risk of conflict with port traffic and vessel movement
Maritime legal compatibility	Maritime rules are mature, but rarely linked to UAV provisions	Weak legal interoperability at the sea–air interface	Ambiguity over responsibility, liability, and safety oversight
Institutional governance	Multiple authorities involved (aviation, port, maritime, security)	No single lead authority for approvals	Fragmented decision-making and slow operationalization
Infrastructure readiness	Limited drone-specific port facilities	Lack of designated launch/recovery and delivery interfaces	Reduced safety, efficiency, and routine feasibility

Source: Authors.

BVLOS in port and coastal areas; and means of mutual recognition of operator qualifications when appropriate.

B. Digital Single-Window Permitting

The concept of a digital single window system would ensure that flight plans, technical details, insurance, payloads, and emergency procedures can be submitted through one streamlined process and reviewed simultaneously by aviation, ports, and maritime officials.

C. Standardized safety and Security Protocols.

Ship-to-drone operations require port-specific risk assessment, communication-loss procedures, cyber-resilience controls, emergency recovery planning, and additional safeguards for hazardous, restricted, or high-traffic environments.

D. Drone-Ready Port Infrastructure.

The ports need to progressively have designated launch and recovery zones, secure operational paths, delivery points compatible with vessels, charging facilities, geofencing systems, and integration of data with the port community system or unmanned traffic management systems.

E. Coordinated Institutional Governance.

The inter-agency coordination framework must link civil aviation, maritime agencies, port operators, and relevant security partners. Regulatory sandboxes and piloting environments can aid in the development of rules based on evidence, while simultaneously mitigating any operational risks.

These five pillars will turn disparate compliance frameworks into an interoperable governance framework for maritime drone logistics.

Table 2: Key barriers and corresponding framework responses.

Identified Barrier	Observed Effect	Framework Response	Expected Outcome
Fragmented UAV regulations	Inconsistent authorization and legal uncertainty	Regulatory harmonization	Clearer legal pathways for maritime drone operations
Weak inter-agency coordination	Slow approvals and duplicated processes	Digital single-window permitting + coordinated governance	Faster, more predictable approvals
Absence of port-specific operating standards	Unsafe or non-repeatable deployment conditions	Standardized safety and security protocols	Safer and more replicable operations
Limited port infrastructure for drones	Operational inefficiency and landing/recovery constraints	Drone-ready port infrastructure	Improved operational readiness and reliability
Lack of pilot-to-policy transition mechanisms	Pilots remain isolated and non-scalable	Regulatory sandboxes and phased implementation	Easier scaling from trials to routine operations

Source: Authors.

Table 3: Illustrative implementation lessons.

Example Context	Illustrative Lesson for the Paper
Singapore shore-to-ship drone trials	Predefined aerial corridors and controlled port environments improve feasibility
Port drone network deployments	BVLOS operations become practical when command-and-control systems are integrated
Port security/inspection drone use cases	Institutional buy-in increases when drones are linked to measurable operational value

Source: Authors.

6. Discussion.

As such, the results show that the critical issue in ship-to-drone logistics operations is not so much technical feasibility but governance interoperability. The research therefore presents a new policy and management agenda that shifts focus from the mere authorization of UAVs to regulation, coordination, and standardization efforts.

To the policy makers, the framework presents a clear path toward achieving a balance between innovation and safety / security without increasing uncertainties. To the port authorities, it represents a practical guide for achieving readiness in stages starting with pilot corridors and maturing into full-fledged infrastructure and permitting. To logistics operators and service providers, the framework outlines the governance requirements for predictable commercial deployment.

The framework is particularly useful to nascent and developing maritime economies that have an increasing interest in smart ports and logistics. Unlike previous studies that primarily focus on UAV regulation or smart ports independently, the proposed framework integrates aviation, maritime, and port governance within a single operational model.

Conclusions.

The findings indicate that fragmented governance across aviation regulation, maritime law, and port administration remains one of the main barriers to the implementation of ship-to-drone logistics. Although maritime governance frameworks are generally well established, existing UAV regulations are often not designed to accommodate operations involving vessels as points of departure or destination.

In response to this challenge, the paper proposes a unified regulatory and operational framework built around five interconnected pillars. The framework brings together the legal, institutional, operational, and infrastructure requirements necessary to support the integration of drone operations into maritime logistics. In doing so, it contributes to the literature by linking aviation regulation, maritime governance, and port operations within a single practical framework.

Given the scope of this conference paper, the research is intended as an exploratory conceptual contribution rather than a fully validated implementation model. The proposed framework has not yet been empirically evaluated across multiple ports or tested under real-world operational conditions. Consequently, it should be regarded as a structured foundation for future investigation. Subsequent research could strengthen and refine the framework through expert Delphi studies, pilot implementations in port environments, and comparative assessments across different regulatory and institutional contexts.

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References.

Cimino, M.G.C.A., Palumbo, F., Vaglini, G., Ferro, E., Celandroni, N. and La Rosa, D. (2017) 'Evaluating the impact of smart technologies on harbor's logistics via BPMN modeling and simulation', *Information Technology and Management*, 18(3), pp. 223–239. doi:10.1007/s10799-016-0266-4.

European Commission (2019) 'Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft', *Official Journal of the European Union*, L152, pp. 45–71.

European Union Aviation Safety Agency (EASA) (2024) *Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)*. Revision of July 2024. Cologne: European Union Aviation Safety Agency.

Heilig, L., Lalla-Ruiz, E. and Voß, S. (2017) 'Digital transformation in maritime ports: Analysis and a game theoretic framework', *Netnomics: Economic Research and Electronic Networking*, 18(2–3), pp. 227–254. doi:10.1007/s11066-017-9122-x.

Heilig, L. and Voß, S. (2017) 'Information systems in seaports: A categorization and overview', *Information Technology and Management*, 18(3), pp. 179–201. doi:10.1007/s10799-016-0269-1.

International Civil Aviation Organization (ICAO) (2015) *Manual on Remotely Piloted Aircraft Systems (RPAS)* (Doc 10019). Montreal: ICAO.

International Maritime Organization (IMO) (1974) *International Convention for the Safety of Life at Sea (SOLAS)*. London: IMO.

Mid-West Ports Authority (n.d.) *Drone Operations Over Port Lands and Waters Procedure*. Western Australia: Mid-West Ports Authority.

Stolaroff, J.K., Samaras, C., O'Neill, E.R., Lubers, A., Mitchell, A.S. and Ceperley, D. (2018) 'Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery', *Nature Communications*, 9, Article 409. doi:10.1038-/s41467-017-02411-5.

United Nations (1982) *United Nations Convention on the Law of the Sea (UNCLOS)*. New York: United Nations.

United Nations Conference on Trade and Development (UNCTAD) (2023) *Review of Maritime Transport 2023*. Geneva: United Nations Conference on Trade and Development.

Wang, J., Zhou, K., Xing, W., Li, H. and Yang, Z. (2023) 'Applications, evolutions, and challenges of drones in maritime transport', *Journal of Marine Science and Engineering*, 11(11), Article 2056. doi:10.3390/jmse11112056.